Juvenile Height Growth of Four Upper-Slope Conifers in the Washington and Northern Oregon Cascade Range

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by

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PACIFIC NORTHWEST
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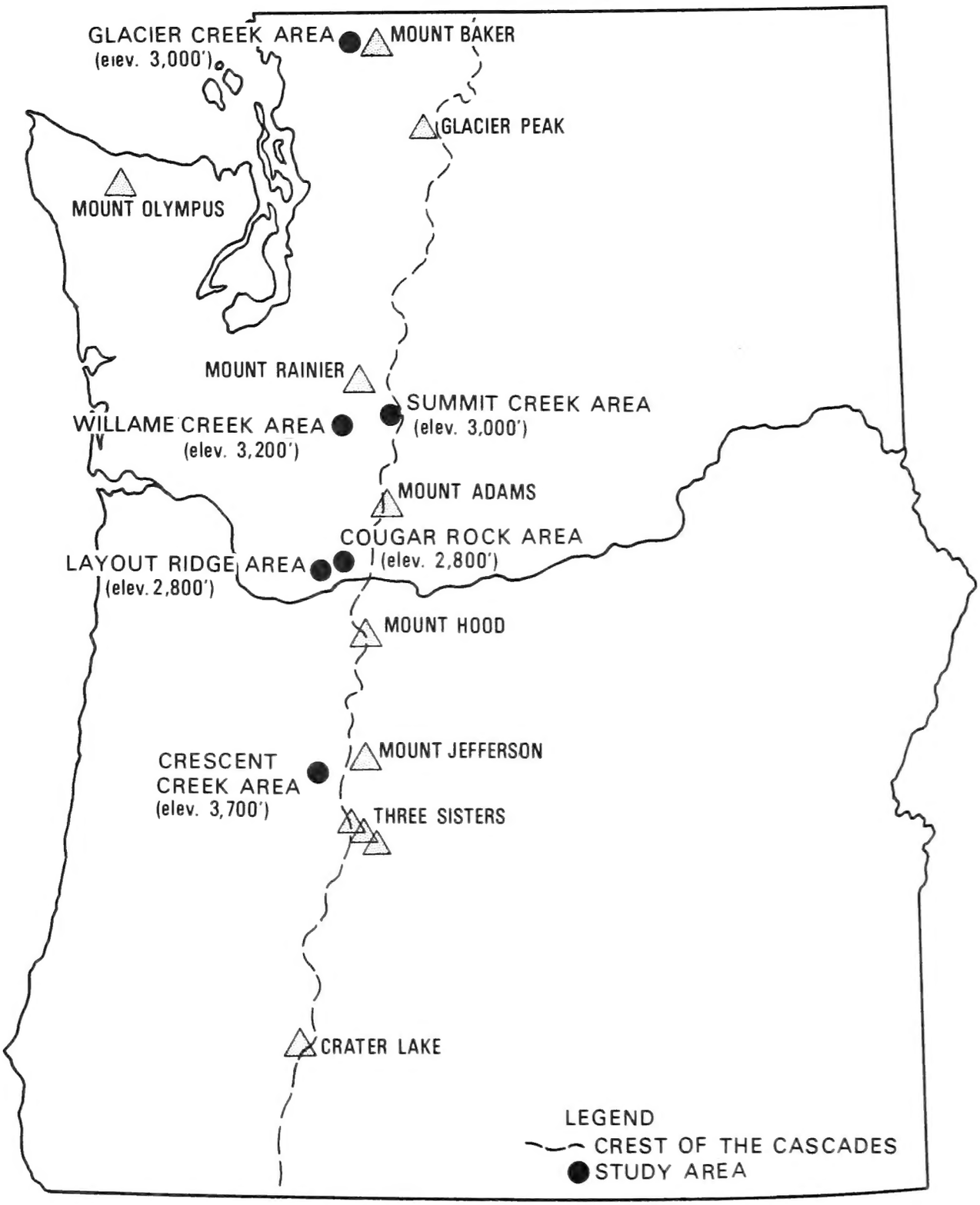

Figure 1.--Locations of the six study areas. All areas except Summit Creek had northern or northeastern aspects.

INTRODUCTION

True fir-hemlock forests cover over 3 million acres at the middle-to-high elevations--the upper slopes--of the Cascade and coastal mountain ranges of Oregon and Washington. These forests are characterized by a mixture of Pacific silver fir, *Abies amabilis* (Dougl.) Forbes; western hemlock, *Tsuga heterophylla* (Raf.) Sarg.; western white pine, *Pinus monticola* Dougl.; and mountain hemlock, *T. mertensiana* (Bong.) Carr. Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, is a common and important associate of these species, particularly below 3,500 feet. Pacific silver fir comprises over one-third of the commercial sawtimber volume in true fir-hemlock forests and western hemlock is second in abundance.

Utilization of the upper-slope forest resource is expanding because of increasing accessibility and demand for the species. Patch clearcutting is a common harvesting method, particularly in the northern part of the Cascade Range. Clearcuts, usually 40-60 acres in size, are generally slash-burned and then planted, seeded, or allowed to regenerate naturally. There are good opportunities to at least partially control composition of the new stand.

Selection of species to manage is difficult in true fir-hemlock forests because of (1) the large number of species and wide variety of habitats present, (2) lack of knowledge of growth rates of upper-slope species, and (3) the earlier low demand for several upper-slope species. Foresters often plant Douglas-fir on clearcuts. Planting success has been variable, sometimes promising at lower elevations but less successful with increasing elevation. Noble and Shasta red fir are the only true firs planted to any extent and some of these plantings have been failures. Some ponderosa pine, *Pinus ponderosa* Laws., is planted on southern exposures in central and southern Oregon.

True firs grow very slowly during their early years (Baker 1950). A series of studies on the adaptability of tree species to forest sites on Vancouver Island showed seedling Pacific silver fir had the poorest height growth of all the conifers and only fair survival (Schmidt 1959, 1960, 1961). The only juvenile growth study involving an upper-slope true fir in the Cascades was by Hanzlik (1925). At Larch Mountain in Oregon, he found noble fir took an average of 11 years to reach a height of 4.5 feet.

The present study compares the juvenile growth rates of noble fir, Pacific silver fir, Douglas-fir, and western white pine on six areas in the Washington and northern Oregon Cascade Range (fig. 1).

Figure 2.--Young Pacific silver firs usually were found growing in the shade.

METHODS

Growth was analyzed for Pacific silver fir, noble fir, western white pine, and Douglas-fir seedlings and saplings up to 4 inches diameter breast height (d.b.h.) on five clearcuts in the southern Washington and northern Oregon Cascades. The clearcuts were 15 to 20 years old at the time of the study and contained mixed natural reproduction of upper-slope species. Not all four species were present or adequately represented on all five areas; consequently, comparisons by area sometimes involved less than four species.

A Douglas-fir plantation in the Mount Baker area of northern Washington also was sampled to compare the juvenile growth of Douglas-fir and Pacific silver fir. The Douglas-fir plantation was planted at a 12- by 12-foot spacing and contained many volunteer Pacific silver fir and western hemlock seedlings and saplings--some were advance reproduction surviving the logging and burning operations, and others had seeded-in after the plantation was established. Five of the six study areas had northern to northeastern aspects. Slopes ranged from 3 to 40 percent, and elevations ranged from 2,800 to 3,700 feet. The Summit Creek area in central Washington had a southern aspect and was at an elevation of approximately 3,000 feet.

The four species were distributed differently on the study areas. Except at Glacier Creek, Pacific silver fir seedlings and saplings generally grew in groups within 100 feet of mature timber stands (fig. 2). Beyond 100 feet, they were most frequently found in the shade of other species.

Douglas-fir and noble fir reproduction was more numerous within 150-200 feet of adjacent stands than elsewhere, but also was well represented in the center of the clearcuts (fig. 3). These species sometimes grew in groups but less often than Pacific silver fir. Western white pine seedlings were sparse but well distributed throughout all study areas. Sapling-size pines were rare.

Field and Laboratory Procedure

The objective was to measure a 20-tree sample of each species on each study area, 10 to be seedlings from 6 feet tall to 2 inches d.b.h. and 10 to be saplings 2 to 4 inches d.b.h. The two size classes were used because, presumably, tree ages would span a considerable period of time and tend to average out effects, if any, of short-term weather cycles. Trees were to be free-growing with at least 5 feet of space around the crowns and without evidence of major leader injury. Number of trees was less than 20 on some areas because not enough trees met these criteria. The criterion for free-growing trees was relaxed for Pacific silver fir because of the groupwise occurrence of this species. Some study trees were the most vigorous and least crowded in a particular group but did have crowns of competitors within 5 feet.

The dominant species of arborescent and nonarborescent flora were listed for each study area, along with environmental features such as soil, aspect, humus type, and elevation (table 1).

A

Figure 3.--*A*, mixed stand of young Douglas-fir and noble fir. Density is typical of young stands within 150-200 feet of adjacent mature stands. *B*, mixed stand of young Douglas-fir, noble fir, and western white pine. Picture was taken in same stand as *A*, but more towards the center of the clearcut--approximately 300-400 feet from boundary of adjacent mature stand. Douglas-fir's juvenile growth generally exceeded that of its associates on this area.

B

Study trees were cut flush with the ground, lateral branches removed, and stems labeled as to species, tree number, and study area. Leader growth was measured to the nearest tenth of an inch. Trees were cut at Glacier Creek after the end of the 1964 growing season and from other study areas at the end of the 1963 season.

Stems were taken to the laboratory at Corvallis, Oregon, for measurement and dissection. In the laboratory, annual internodal growth was measured on each stem back to the 4.5-foot level. Stems were then sectioned at 2.0-foot height intervals and at the 4.5-foot level. Disks from these sections provided a check for the ages of the various internodes.

Stem analyses showed that all the Douglas-fir, noble fir, and western white pine study trees became established after logging, whereas only 35 of 110 Pacific silver fir trees did so. The other 75 silver firs were advance reproduction which had become established beneath the overstory of the forest and survived the logging and slash-burning operations. They had grown very slowly while under the forest canopy, but their height growth increased substantially after the overstory was logged.

Prelogging and postlogging reproduction data were kept separate for general comparisons between species, but combined when comparisons were broken down by locality. Analyses of variance were calculated with all silver fir included, then again with it excluded for better evaluation of variation among the other species.

Table 1.--Plant associations and other characteristics of six areas used to study juvenile height growth of four upper-slope conifers in Washington and Oregon

Study area	Elevation	Aspect	Forest type	Additional tree species present	Important understory vegetation (listed in order of dominance)[1]	Approximate cover	Forest humus type	Average soil depth	Soil texture
	Feet					Percent		Feet	
Summit Creek	3,000	South	Western hemlock-Pacific silver fir	Scattered western redcedar, western white pine; Douglas- and noble firs rare	*Acer circinatum, Linnea borealis, Xerophyllum tenax, Arctostaphylos nevadensis, Vaccinium ovalifolium, V. membranaceum,* and *Menziesia ferruginea*	100	Felty mor	1.4	Gravelly loam
Cougar Rock	2,800	Northeast	Pacific silver fir	Noble fir, Douglas-fir; scattered western hemlock and western white pine	*V. alaskaense, V. membranaceum, Linnea borealis, Pteridium aquilinum pubescens, Cornus canadensis*	90	Felty mor	5.0	Sandy loam
Layout Ridge	2,800	Northeast	Pacific silver fir	Noble fir, Douglas-fir; scattered western hemlock and western white pine	*V. alaskaense, V. membranaceum, V. parvifolium, A. circinatum, C. canadensis,* and *L. borealis*	100	Felty mor	4.0	Sandy loam
Crescent Creek	3,700	Northeast	Western hemlock-Douglas-fir	Noble fir, Pacific silver fir, and scattered western white pine	*Ceanothus velutinus, Rubus ursinus, Xerophyllum tenax*	100	Felty mor	4.5	Silt loam
Willame Creek	3,200	North	Western hemlock-Pacific silver fir	Douglas-fir and scattered noble fir	*L. borealis, V. alaskaense, C. canadensis, Epilobium angustifolium, A. circinatum*	100	Felty mor	3.0	Gravelly loam
Glacier Creek	3,000	North	Pacific silver fir-western hemlock	None	*P. aquilinum, R. parviflorus, R. spectabilis, V. ovalifolium, Oplopanax horridum*	100	Felty mor	--	Sandy loam

[1]Common and scientific names for trees are in accordance with Little (1953); for shrubs and herbs, Peck (1961) or Hitchcock et al. (1955-1964).

RESULTS

Some species became established more rapidly after clearcutting than others as shown by significant differences among ages of study trees. This was true even with the older Pacific silver fir reproduction excluded (table 2). Douglas-fir was the first species to become established at Summit Creek followed by western white pine and noble fir. Noble fir was first at Layout Ridge and Willame Road.

Except for Pacific silver fir generally and Douglas-fir at Summit Creek, stem analyses showed little age difference between seedlings and saplings (table 2). This finding largely eliminated the possibility of averaging out effects of any short-term climatic cycles. On the other hand, it indicated wide variation in growth rates among trees of the same species on the same cutting area, even when most trees presumably were free of competition. Analyses of variance on growth rates between seedlings and saplings, based on 1957 to 1963 internode lengths, showed that the saplings had grown significantly faster than the seedlings during this period. The saplings, then, were the most vigorous among the free-growing trees, and their growth probably approximates the best individual tree growth obtainable on the sites studied. Combined seedling and sapling data probably approximate early growth data of an intensively managed stand where trees are spaced widely enough to minimize competition.

In contrast, Pacific silver fir saplings were almost twice the age of the seedlings (table 2), requiring approximately twice the time seedlings needed to reach a height of 4.5 feet. Since the majority of Pacific silver fir seedlings and saplings were advanced reproduction, it appears that overstory canopies were denser when the saplings were established than when the younger seedlings were established.

Years required to reach 4.5 feet in height varied by species and area (table 3). Pacific silver fir took far longer than other species, but the data include the very slow-growing advanced (prelogging) reproduction. If we consider both seedlings and saplings, noble fir grew significantly slower than Douglas-fir at Willame Road and significantly slower than Douglas-fir and western white pine at Layout Ridge. There seemed to be a reversal at Summit Creek, where noble fir grew faster than Douglas-fir and western white pine on an exposed southern aspect at 3,000-foot elevation, although the difference among the species was significant only in the sapling-size class. Except for the slow-growing silver fir, all species grew about the same on the other areas.

The 1957-63 height growth differed greatly among species on each study area. With the exception of noble fir and western white pine saplings at Summit Creek, Douglas-fir outgrew all other species. Pacific silver fir always demonstrated the slowest growth. Western white pine outgrew noble fir on two areas, and noble fir was slightly better than pine on two others (table 4).

Total height-growth data from individual study areas showed no exception to Douglas-fir's superiority. However, it was not significantly different from its associate species at Layout Ridge and Crescent Creek (table 5).

Table 2.--Average age of study trees by area, size class, and species, with number of trees and significance level of difference among species

Area and size class	Tree species				Significance level[1]	
	Douglas-fir	Noble fir	Western white pine	Pacific silver fir	With no Pacific silver fir	With all Pacific silver fir
	Years					
Summit Creek:						
Seedlings	12.7	11.4	13.6	26.9	NS	**
Saplings	21.7	12.5	14.0	92.1	**	**
All	17.2	11.6	13.8	61.8	**	**
Cougar Rock:						
Seedlings	11.4	12.1	10.2	28.3	NS	**
Saplings	13.3	12.8	11.7	50.9	NS	**
All	12.4	12.5	10.7	39.6	*	**
Layout Ridge:						
Seedlings	10.7	12.7	10.8	27.4	**	**
Saplings	12.5	13.7	12.0	61.8	NS	**
All	11.6	13.2	11.0	44.6	**	**
Crescent Creek:						
Seedlings	11.0	11.8	11.1	([2])	NS	--
Saplings	12.2	12.0	11.3	--	NS	--
All	11.4	11.8	11.2	50.6	NS	**
Willame Road:						
Seedlings	10.7	11.8	--	48.7	NS	**
Saplings	11.3	12.8	--	87.6	**	**
All	11.0	12.3	--	68.2	**	**
Glacier Creek:						
Seedlings	10.5	--	--	14.3	--	**
Saplings	12.2	--	--	26.0	--	**
All	11.4	--	--	20.2	--	**

[1] * – 0.05 level of significance
** – 0.01 level of significance
NS – Nonsignificance level.

[2] No breakdown of data available for seedlings and saplings.

Table 3.--Average years study trees required to reach height of 4.5 feet, by area, size class, and species, with significance level of difference among species

Area and size class	Tree species				Significance level[1]	
	Douglas-fir	Noble fir	Western white pine	Pacific silver fir	With no Pacific silver fir	With all Pacific silver fir
	Years					
Summit Creek:						
Seedlings	7.8	7.5	10.0	22.2	NS	**
Saplings	10.0	5.5	6.9	72.7	**	**
All	8.9	7.2	8.5	49.1	NS	**
Cougar Rock:						
Seedlings	7.8	8.4	8.0	22.3	NS	**
Saplings	5.4	6.2	6.0	39.0	NS	**
All	6.6	7.3	6.7	30.7	NS	**
Layout Ridge:						
Seedlings	7.2	9.3	6.8	21.8	**	**
Saplings	5.9	6.8	5.5	48.5	NS	**
All	6.6	8.1	6.6	35.2	*	**
Crescent Creek:						
Seedlings	7.0	7.2	7.2	([2])	NS	--
Saplings	6.6	5.6	5.0	--	NS	--
All	6.9	6.7	6.7	47.6	NS	**
Willame Road:						
Seedlings	6.3	8.2	--	43.0	**	**
Saplings	5.7	6.1	--	77.4	NS	**
All	6.0	7.2	--	60.2	*	**
Glacier Creek:						
Seedlings	6.5	--	--	8.8	--	**
Saplings	5.9	--	--	17.9	--	**
All	6.2	--	--	13.3	--	**

[1] * – 0.05 level of significance
** – 0.01 level of significance
NS – Nonsignificance level.

[2] No breakdown of data available for seedlings and saplings.

Table 4.--Average internode length from 1957 to 1963, by area, size class, and species, with significance level of difference among species

Area and size class	Tree species				Significance level,[1] with all Pacific silver fir
	Douglas-fir	Noble fir	Western white pine	Pacific silver fir	
	---------- Feet ----------				
Summit Creek:					
Seedlings	1.19	0.97	1.03	0.78	*
Saplings	1.64	1.68	1.72	1.00	**
All	1.39	1.09	1.35	.92	**
Cougar Rock:					
Seedlings	1.04	.77	.84	.60	**
Saplings	1.74	1.35	1.42	.96	**
All	1.37	1.06	1.00	.78	**
Layout Ridge:					
Seedlings	1.15	.87	.97	.72	**
Saplings	1.88	1.47	1.48	1.10	**
All	1.51	1.17	1.05	.91	**
Crescent Creek:					
Seedlings	1.25	1.00	1.12	.79	*
Saplings	1.82	1.51	1.79	--	NS
All	1.44	1.19	1.27	1.17	NS
Willame Road:					
Seedlings	1.23	.97	--	.74	**
Saplings	2.17	1.52	--	1.16	**
All	1.67	1.25	--	.95	**
Glacier Creek:					
Seedlings	1.21	--	--	1.05	NS
Saplings	2.25	--	--	1.59	**
All	1.73	--	--	1.32	**

[1] * – 0.05 level of significance
** – 0.01 level of significance
NS – Nonsignificance level.

Table 5.--Average height of trees, by area, size class, and species, with significance level of difference among species

Area and size class	Tree species				Significance level[1]	
	Douglas-fir	Noble fir	Western white pine	Pacific silver fir	With no Pacific silver fir	With all Pacific silver fir
	Feet					
Summit Creek:						
Seedlings	10.1	8.4	8.3	8.2	NS	NS
Saplings	18.8	15.4	15.5	15.1	*	*
All	14.5	9.5	11.9	12.0	*	*
Cougar Rock:						
Seedlings	8.8	7.6	6.7	8.0	NS	NS
Saplings	16.9	13.1	12.6	14.6	**	*
All	12.9	10.4	8.7	11.3	*	NS
Layout Ridge:						
Seedlings	9.0	7.9	8.4	8.5	NS	NS
Saplings	16.9	14.5	13.6	15.3	NS	NS
All	13.0	11.2	9.3	11.9	NS	NS
Crescent Creek:						
Seedlings	10.2	9.1	9.1	([2])	NS	--
Saplings	15.4	13.6	15.0	--	NS	--
All	11.9	10.6	10.5	9.1	NS	NS
Willame Road:						
Seedlings	9.9	8.3	--	8.5	NS	NS
Saplings	17.3	14.1	--	13.9	**	**
All	13.4	11.2	--	11.2	*	**
Glacier Creek:						
Seedlings	11.2	--	--	10.5	--	NS
Saplings	19.7	--	--	17.5	--	**
All	15.4	--	--	14.0	--	**

[1] * – 0.05 level of significance
** – 0.01 level of significance
NS – Nonsignificance level.

[2] No breakdown of data available for seedlings and saplings.

Since area-species interactions are partial causes of measured differences in species growth on each area, the growth data from all areas were combined to see if the general superiority of Douglas-fir would still show significantly. The inherent superior juvenile growth ability of Douglas-fir became apparent after trees reached the 4.5-foot height (table 6). Douglas-fir grew faster than the other species during the 7 years prior to dissection of the trees, as indicated by a greater 1957-63 average internode length. Its internodal growth rate was followed by western white pine, noble fir, and Pacific silver fir, with differences among the four species significant at the 0.01 level. At the time of cutting, Douglas-fir was taller than the other species.

It was surprising that the 1957-63 growth rate of Pacific silver fir, which included a high proportion of prelogging reproduction, was surpassed by that of other species starting from seed after logging (table 6). Pacific silver firs had responded to release by the clearcutting, but not enough to compete successfully with the more vigorous species. Average total height of all silver firs did slightly exceed that of noble fir and western white pine. On the other hand, silver fir reproduction established after logging, which by ring count had about 2 years' headstart on Douglas-fir, noble fir, and western white pine, was overtaken by them.

Table 6.--Average age, dimensions, and number of study trees by species, with significance level of difference among species

Variable	Tree species					Significance level[1]	
	Douglas-fir	Noble fir	Western white pine	Pacific silver fir		With no Pacific silver fir	With all Pacific silver fir
				All trees	Postlogging trees		
Number of trees	114	87	54	110	35	--	--
Average age (years)	12.5	12.4	12.0	47.2	14.4	NS	**
Average years to reach 4.5 feet	6.9	7.3	7.3	38.6	9.0	NS	**
Average internode, 1957-63 (feet)	1.52	1.15	1.21	.99	--	**	**
Average height (feet)	13.6	10.7	10.4	11.8	10.1	**	**
Average d.b.h. (inches)	2.0	1.9	1.7	2.0	1.4	NS	*

[1] * – 0.05 level of significance
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NS – Nonsignificance level.

DISCUSSION

The most interesting findings of this study were the superior juvenile growth rate of Douglas-fir relative to the true firs and western white pine and the comparatively poor juvenile growth rate of Pacific silver fir trees. But one should not conclude from this that Douglas-fir would necessarily be the best species to manage on the study areas. Evidence is accumulating that any superiority over noble fir and white pine in juvenile height growth of Douglas-fir is not maintained throughout the life cycles of these species on upper-slope sites. The author has observed that noble fir is always a component of the upper-crown canopy of essentially even-aged stands containing western hemlock and the four species studied here. Noble fir and white pine often extend above the average level of the crowns of associated species, including Douglas-fir, indicating that they maintain rapid height growth longer than their associates.

In a 400-year-old mixed stand growing on Douglas-fir site III at Larch Mountain, Douglas-fir and western hemlock diameters initially increased at a greater rate, but noble fir overtook and surpassed them between 100 and 200 years (Hanzlik 1925). In a more recent study, comparisons of height/age curves of free-growing trees in mixed stands confirmed that Douglas-fir initially grew faster than noble fir or Pacific silver fir. At 100 years, they were nearly the same height; and after about 200 years, noble fir almost always was dominant, with Douglas-fir and silver fir in codominant positions (Herman 1967).

Although the Pacific silver fir sample included prelogging reproduction and there was some crowding of study trees, it seems clear this species had slower juvenile growth characteristics than its associates. Its best growth was at Glacier Creek where it could be compared only with the Douglas-fir plantation. Douglas-fir grew significantly faster. Pacific silver fir, however, is an important species in the true fir-hemlock forests of the Pacific Northwest, accounting for over one-third of current timber volume. Seedlings are readily established under mature stands and, as on the study areas, many survive harvesting operations and become an important component of the new stand.

On upper-slope areas, Douglas-fir is more susceptible to snow damage than its associates (Williams 1966). Since only trees without evidence of major leader injury were selected for this study, little or no effect of snow damage is reflected in results. Therefore, when comparing species, one should consider that Douglas-fir reproduction may be more severely damaged by snow than the true firs or western white pine.

Number of years to reach breast height is added to increment core counts at breast height to obtain total age of standing trees. Data in table 3 may be used for this purpose but should be restricted to sites similar to study areas and where trees were free to grow during their juvenile stage. The only comparable data are Hanzlik's taken at Larch Mountain. He found it took noble fir 11 years to reach breast height compared to an average of 7.3 years in this study.

Results presented here permit comparisons of juvenile growth characteristics, but final selections of species to manage in upper-slope areas must await additional research with older age classes.

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Douglas-fir generally exhibited more rapid juvenile height growth than western white pine and noble and Pacific silver firs on upper-slope clearcuts. Pacific silver firs grew slowest even though most were established prior to logging the overstory, in contrast to other species. Although height growth of Pacific silver fir increased dramatically following logging of overstory, it was exceeded by greater height growth of less shade-tolerant species.

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